Proceedings of the MEDSI 2014 Conference

Melbourne, Australia - October 2014

ALBA BOREAS Beamline End Station support elements concept design

Alejandro Crisol, Carles Colldelram, Liudmila Nikitina, Manuel Valvidares
CELLS – ALBA Synchrotron
BP-1413 Km 3,3, Cerdanyola del Vallés, Spain
acrisol@cells.es; ccolldelram@cells.es; lnikitina@cells.es; mvalvidares@cells.es

Abstract **-** BOREAS beamline at ALBA synchrotron facility is soft X-ray beamline dedicated to polarization-dependent spectroscopic investigations of advanced materials. One of the two End Stations, MARES (magnetic resonance scattering) is a non-conventional and complex multicomponent instrument as a reflectometer for a scattering in a UHV environment. The main points of the component are the UHV chamber, the Cryomagnet, the cryomanipulator, sample transference between end stations and detectors. The whole system has to be supported by a stable support with an accurate beam transversal movement. In addition, during sample transference between End Stations, cryomagnet has to be moved. For this purpose ALBA engineering division has developed a support with all mechanism integrated. The goal of the design was to achieve high stability but high resolution movements in turn and all for a big massive and tall set up. The concept is based on a first fixed stage of support composed by four angled natural granite columns acting as a pyramid with a frame where the transversal movement is mounted. After that, vacuum chamber and all the instrumentation are mounted over adjustable base plate system (X, Y, Z regulations) and X axis movable. The tool that support, moves and adjust the position on magnet is mounted also on the base plate. Despite of the big mass, there is a close to 2 tones system that can be moved perpendicularly to the beam with 0,2µm resolution keeping the first resonance mode placed over 40Hz, far from floor excitations. Regarding vertical movement of the magnet, it can be done with 1µm resolution and it can be tilted independently of support or vacuum chamber. To reach a proper design several solutions have been proposed and analysed with FEA tools to validate a compromise solution which has been finally produced. Some tests have been performed whose results verify the design capabilities.

1. Introduction

BL29, Boreas is dedicated to advanced materials experimentation with a magnetic dependence. The source of the Beamline is an elliptical undulator, an APPLE II. The optics layout, starting with de ID, and the most important elements are:

First section is composed by plane and toroid mirrors (PM and TM, respectively). Their function is to absorb most of the heat load delivered from the source and to prepare the beam for the monochromator by focusing it in the vertical plane. The second section consists of the monochromator: this is based on variable line spacing (VLS) plane gratings (PGs). The monochromator is equipped with both entrance and exit slits and is dispersing in the vertical plane. The third section comprises the refocusing optics, consisting of two bendable mirrors arranged in a Kirkpatrick-Baez geometry, where the first mirror (PE1) is vertically focusing, while the second mirror (PE2) is horizontally focusing. This system allows to focus the beam at either of the two experimental stations.

At the end, the two End Stations are placed, Hector and Mares. The first one, HECTOR, is a superconducting magnet with a three orthogonal coils that produce a maximum field of 6 Tesla vector, on the Beam plane, and 2 Tesla vector at any direction that provides an available 2 Tesla sphere. It contains three stages preparation chamber to introduce samples. And samples are mounted on a sample holder attached to the cold finger of a cryostat, with temperatures variable between 2 and 350K. This End station is fully operative since two years ago.

The second one is MARES. MARES is a scattering resonance end station, it is a complex multicomponent instrument with a different subsystems. Vacuum chamber is the central component where the rest of components are mounted.

Fig. 1. Beamline Layout, before summer 2014

On the picture, both end stations are place on the same movable platform. There were some stability weaknesses, especially on HECTOR, that has done to reject the original configuration. On 2014 summer, big intervention has been performed to separate every station and fix it on the floor as usual.

In addition, between End Stations, there is a sample transfer system. With this system is possible to introduce samples into the system or move samples between end stations. Taking into account the two sample loadlock systems available at every end station, there is a big UHV system to prepare and transfer samples between end stations. On Figure 2, taken after the summer intervention, the movable platform has been removed and every system has been placed on base plates with epoxy fixation to the floor.

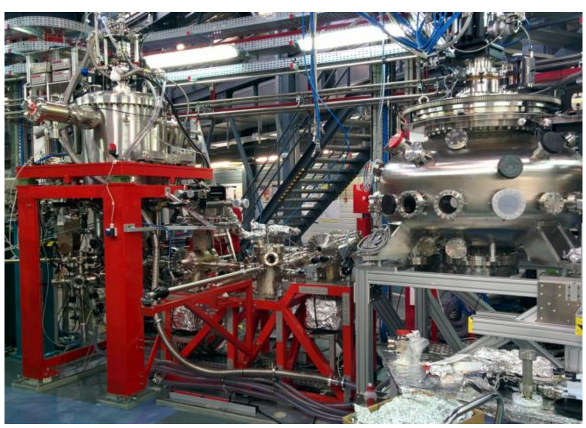
Fig. 2. End Stations and Sample transfer

Finally, between end stations following the beam path, will be installed some external detectors and MARES slits. These components are not shown on the last figure.

2. MARES mechanical specifications

The design is centered now on the MARES End Station. The specifications for the new equipment are based on the scientific requirements and taking into account the huge number of elements that is involved.

2. 1. MARES components

MARES is a multicomponent system with a central UHV chamber. After that, there are a lot of subsystems involved. The most important are:

Cryomagnet, It is a 2 Tesla cryomagnet that provides a magnetic field to the sample. This magnet is attached to a rotary feedthrough that gives the possibility to rotate the magnet close to 360º. Cryomanipulador, it is a system with 4 degree freedom that can support the samples at nitrogen or helium temperature. Detectors, at the moment we have two detectors inside de vacuum chamber that are place on a rotary stage. This rotary stage has an extra rotation where the cryomanipulator is placed. This is a ϴ - 2ϴ stage to positioning the sample and the detectors according the beam, the magnet and the experiment. After that, there is a sample loadlock to introduce samples. There are vacuum components as sensors, valves and pumps. Some experiments accessories, like evaporators. And finally, the interaction with the sample transfer system that provides to MARES the samples of HECTOR or other systems.

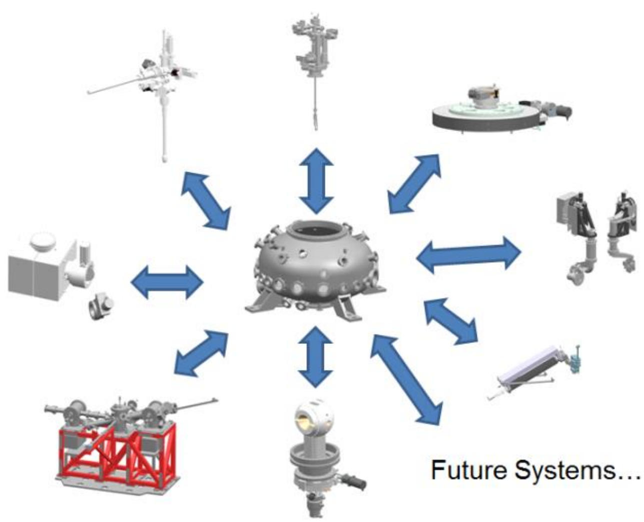

Fig. 3. End Station components

All subsystems must be supported properly, moved and positioned at a certain point with guaranties.

Regarding all components, there are two principal systems to be design, the main support of End Station and the tool that moves the magnet.

2. 2. MARES End Station support

The first system to be design is the support of the End Station. This support has to be rigid enough to support all the components and has to have the capacity to achieve the following characteristics:

High stability to ensure the experiments. Axis regulations to compensate manufacture misalignments. An important one, a transversal to beam movement of +/-20mm has to be included with a very small accuracy. This mince, that all systems must be attached to a movable platform, with the suitable support, because the vacuum chamber and the rest of systems have to be moved. Finally, under the support the empty space must be maximized to accommodate the second system that is the magnet tool.

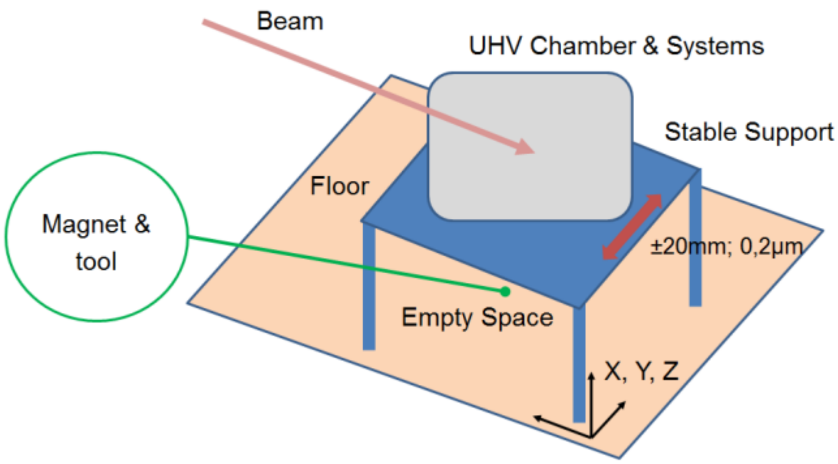

Fig. 4. Support scheme specifications

2. 3. Magnet tool

The Magnet tool is the device that has to allow the vertical movements of the magnet inside or outside of the vacuum chamber and is placed on the support movable parts because the magnet has to be moved with the chamber. The main specifications are:

The system has to provide an easy extraction of the magnet and two precise movements, one to transfer samples arriving from sample transfer, and other to extract the magnet. In addition, some spatial regulations must be included.

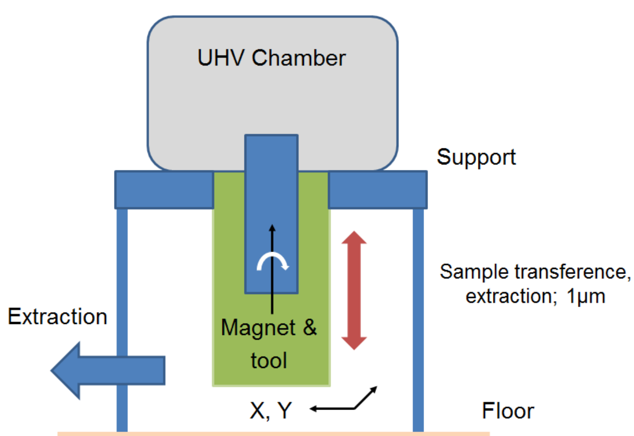

Fig. 5. Magnet tool scheme specifications

3. End Station support conceptual design

The final conceptual design of Mares support can be separated into two different parts, one is fixed to the floor and the other is movable thanks to linear guides and spindle. The main solutions are:

- Fixation of the system to the floor, with base plate reference fixed with epoxy layer.
- The introduction of four natural granite columns with an oblique way acting all together as a pyramid. This configuration gives to the system a high stability with a big free space inside.
- There is an intermediate stage with linear guides and two spindles to perform the transversal movement.
- There are two X,Y regulations, on the floor and on the intermediate stage. In this stage there is the Z regulation.
- Finally, free base plate to place vacuum chamber and all subsystems

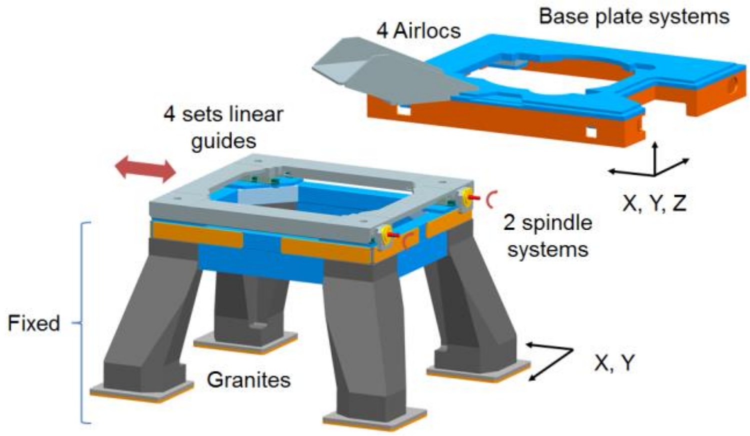

Fig. 6. MARES support structural details

Regarding the characteristics of the movable elements involved on the support, there are 2 sets of linear guides with 2 carriages at every column to ensure stability of the assembly. The values of these guides applied on simulation are shown (Web-1, Web-2, Web-3):

Table 1: Elements stiffness values

Characteristic	***Value***
Guides	$1\cdot10^{9}$ N/m
Spindle support	$4{,}5\cdot10^{8}$ N/m
Spindle nut	$7{,}16\cdot10^{8}$ N/m
Spindle	$1{,}8\cdot10^{9}$ N/m
Total System Spindle	$2{,}4\cdot10^{8}$ N/m

The spindles are placed between guides to ensure that the spindles are not seeing any force except the axial force. The total rigidity is given by the individual values of every component.

4. Magnet tool conceptual design

The concept of the tool that gives the vertical movement to the magnet is placed under the main support and fixed on the movable base plate. This mince that all the tool is moving together with the rest of the systems.

There are three main parts of the magnet tool. First of all, there is the magnet holder or frame. The second part is the vertical movement part. And the last one is the fixed part, the base plate of the vertical movement system. According these three parts, the main solutions applied are:

- Small regulation of X,Y is allowed between the tool and the support.
- Small tilt of magnet adjustment.
- Classical one direction linear movement based on two linear guides and one spindle. The spindle moves up and down the magnet. There are two different positions, one for sample transference and another to extract the magnet.
  - There are two horizontal intermediate linear guides that allow moving the magnet in horizontal direction at lowest position and then, the magnet can be extracted out the support.

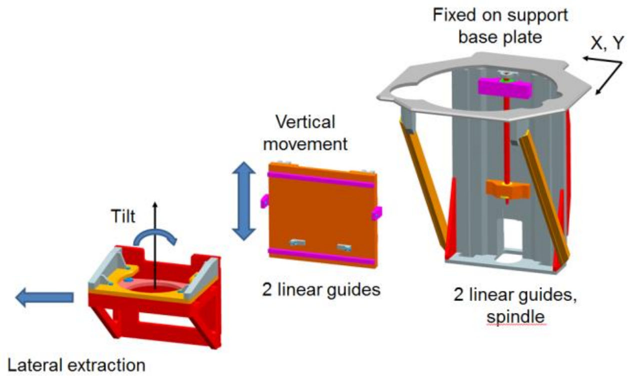

Fig. 7. MARES support structural details

The movement elements of the magnet tool follow the same methodology of the support elements. In this case there are two different linear guides, two vertical with 3 carriages every one and, two horizontal with 2 carriages every one. Values of every typology are shown on the Table 2, and are taken to realize simulation.

Table 2: Elements stiffness values

Characteristic	***Value***
Vertical Guides	$1 \cdot 10^9$ N/m
Horizontal Guides	$8 \cdot 10^8$ N/m
Spindle support	$4 \cdot 10^8$ N/m
Spindle nut	$6 \cdot 10^8$ N/m
Spindle	$2{,}5 \cdot 10^8$ N/m
Total System Spindle	$1{,}22 \cdot 10^8$ N/m

Regarding spindle, in this case there is only one spindle, the total rigidity of the set is given by the different elements too.

5. Conceptual design. Simulations

Putting the two systems together, this is the main conceptual design ready to realize simulations:

Fig. 8. End Station conceptual design

There are the vacuum chamber and different dummies that represents the different subsystems of the end station. The masses of the dummies are according the real mass. The total mass of the movable system, at the end is close to two tones.

Once the conceptual design is done, it is important to verify the behavior under external excitations. The ALBA excitations coming from the floor are on the range of 15-35Hz. The system resonance modes must be over of this range. As normal rule, we take the reference value of 40Hz. If the first resonance mode is over 40Hz it is considered acceptable.

After simulation a big list of resonance modes appear, but the entire values are over 40Hz:

Table 3: Six first system resonance modes

Characteristic	***Value***
1st Mode	42,5 Hz
2nd Mode	49 Hz
3rd Mode	54,4 Hz
4th Mode	56,5 Hz
5th Mode	62 Hz
6th Mode	63 Hz

The behavior of the first resonance mode is the movement along the guides and against the spindles. The granite columns are fixed and the movement is unappreciable, but, the rest of the assembly moves along the guides and against the spindles (Figure 9).

The second and the other modes of vibration are oscillations of the movable part in different directions, all of them conditioned to the pyramid configuration. This fact validates the pyramid configuration of the granite columns.

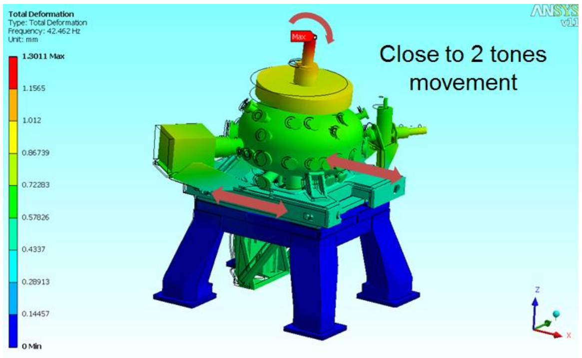

Fig. 9. First resonance mode behavior

Regarding static simulations, gravity and vacuum are the principal loads. Due to the big rigidity of the systems the stress values that appears are very low, less than 15MPa, that is consider close to negligible. The deformations that appears on the main support are low that 0,05mm and the displacement of the magnet due to vacuum is 0,15mm. This value is under 0,2mm that is considered acceptable. Anyway, this small deviation can be compensated with the adjustments placed on the magnet tool.

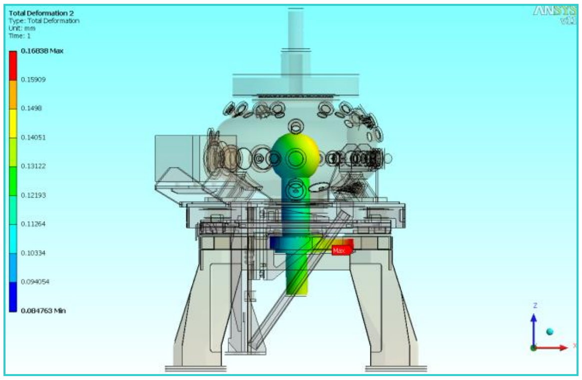

Fig. 10. Magnet displacements

Finally, it is important to consider the movement characteristics. On the transversal movement of the base movable support, there are two steeper motors plus two spindles. These two systems must be moved together as a pseudo-motor, and the main values are: ±20mm range and accuracy less than 0,2µm.

The magnet tool has one movement with two different limits. The sample transference movement has a 264mm travel and the extraction movement has a 520mm travel. This movement is provided by a one steeper motor with final accuracy less than 1µm. The extraction movement is not a common movement, basically is introduced to dismount the magnet during maintenance or breakdown.

In summary, the conceptual design is validated according the simulations done and the previous specifications.

6. Detailed design. Manufacturing

After the conceptual design approval, the design is detailed:

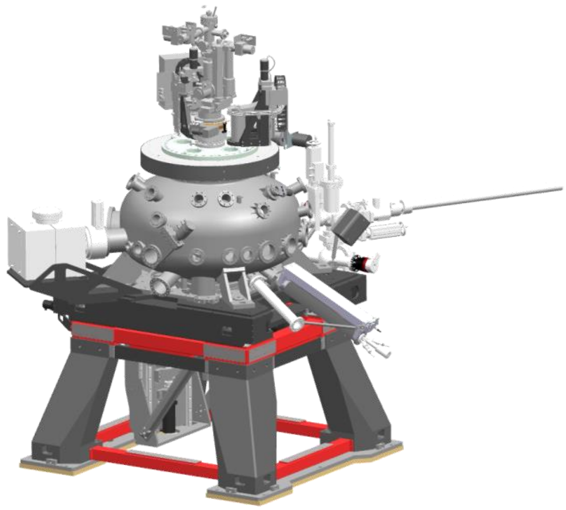

Fig. 11. Detailed design

Due to the high demanding design specifications, the manufacturing went to a quite conventional outsourcing. The adjudication is organized in different sets depending on the characteristics of the production process: huge tolerances parts, easy machining parts, big parts, granites and steel frame.

7. Assembly. Stability preliminary results

Once the parts are being manufactures, the assembly can be started. Due some planning issues, only the support is already done. The magnet tool system will be mounted on the 2014 first months.

Anyway, the support has been assembled with minor problems and the most important components, as the vacuum chamber, have been installed.

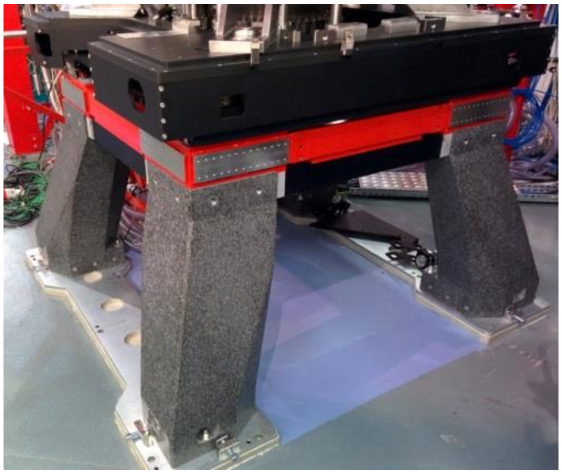

Fig. 12. Support final assembly

Although the system is not complete and mass of magnet and magnet toot are not present, a preliminary test of stability has been perform. Piezoelectric accelerometers has been used, one at every spatial direction. The measurements have been done with accelerometers. One at every direction on the support mobile platform:

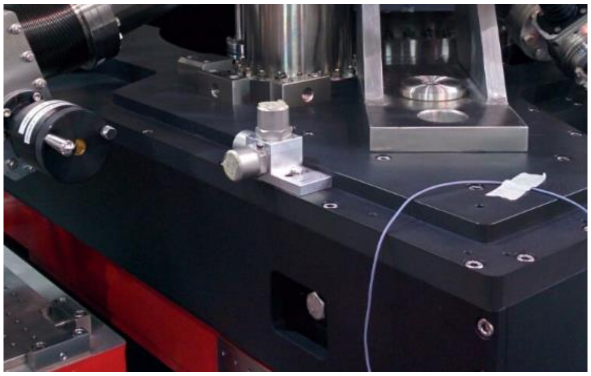

Fig. 13. Three axis accelerometers position

The first measurement has been done at spindles direction, which is the weakest direction. Small excitation has been introduced to see the resonance modes:

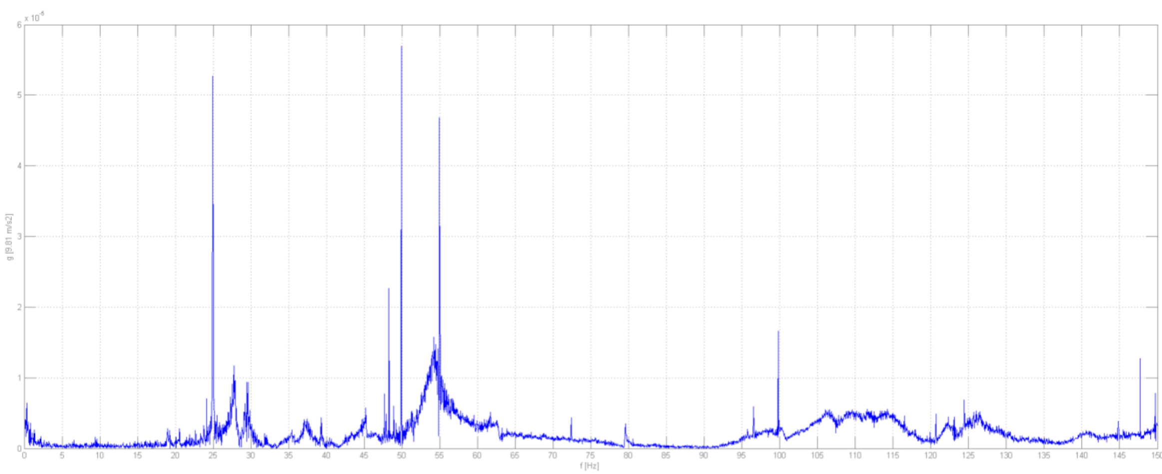

Fig. 14. Transversal direction measure

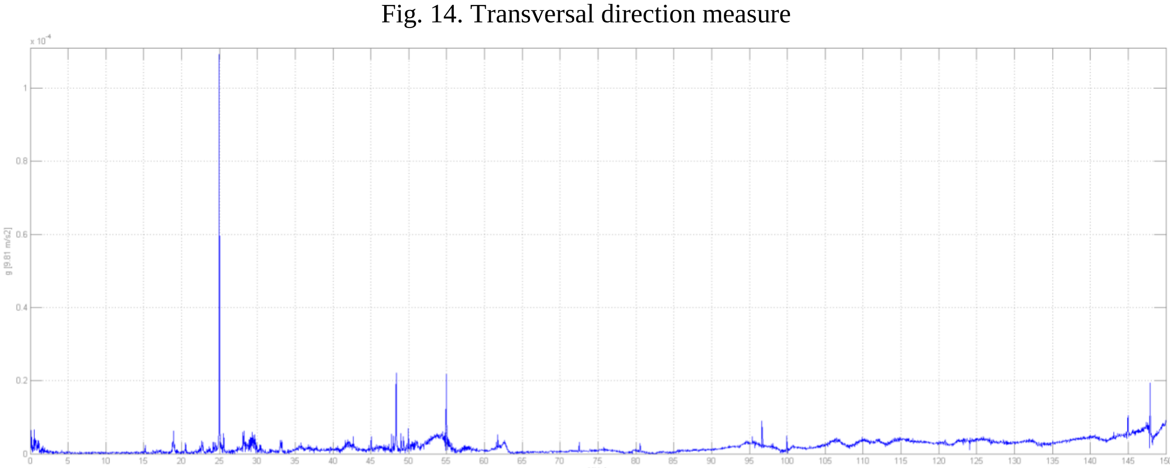

Fig. 15. Longitudinal direction measure

Discarding the peaks of 25, 50 and 100Hz that are coming from electrical motors, it can be observed that the biggest peaks of resonance are all over 45-50Hz. This matches with the previous calculations and give an accurate idea of the final behavior of the support. It is important to remember that there is no the entire weight on the support (halt a tone is missed, 25% of the total). Anyway, the support is working fine according to the calculations.

It must be noted the peaks that appears between 20-30Hz. After the investigation of the origin of these peaks, this noise is observed on the long arms of the loadlock system. During the simulations these arms where eliminated to avoid low frequency noise resonance modes. In principle, these low frequency small peaks have not been taken into account.

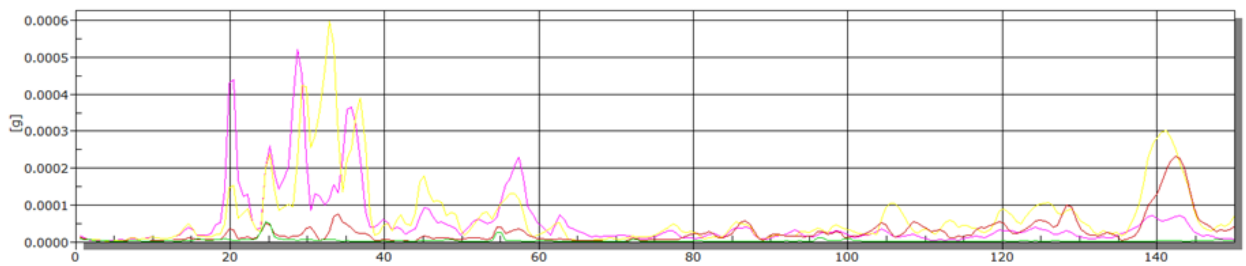

Fig. 16. Noise appeared due to long arms of loadlock system

Small comment about the movement of the platform, a preliminary test has been done to move the two motors together and regulate the limit switches. The test has been done with no big problems and the range of ±20mm is available with no collisions. ALBA-CELLS control group is working, at data of paper publication, on the closed loop control and motors drive into the general beamline control system.

8. Conclusions

Stable and capable support was needed to include a huge list of heavy and different equipment. The interaction of all these components to perform the different experiments required extra system that has been included in addition to the support.

Engineering division has proposed a conceptual design to accomplish the scientist specifications. The concepts have been calculated and tested with FEA analysis to be approved.

Once the detailed design has been implemented, manufacturing and assembly of the first system has been done and the support has been tested. Although all mass are not already placed on the support, the first results shows the stability quality of the system.

Although there is a big mass involved on the system and the big height where is placed, the design of a very accurate and stable support has been achieved. In addition, the simulation of elements involved during the design process has been very precise if we compare the results with the simulations.

Finally, it is important to kwon that there is no collision between elements giving to the scientist fully capability for the next years operation.

Acknowledgements

Authors wish to acknowledge all mostly involved in the design and construction: Engineering Alignment group, Marta Lloch and Jon Ladrera; Mechanical workshop staff, José Ferrer, Karim Maimouni, David Calderón and Oscar Borrego; Optics group, Josep Nicolas; Controls group, Xavier Serra, Xavier Fariña and Fulvio Becherri.

References

Web sites:

Web-1: https://www.thk.com/

Web-2: http://www.schneerberger.com/

Web-3: http://www.skf.com/

Web-4: http://www.stoegra.de/